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(54) Title of the Invention: Dispersant for an Aqueous Slurry of Carbonaceous Fine Powder

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(57) Claims

1 A dispersant for an aqueous slurry of carbonaceous fine powder characterized in that it contains

(A): an aromatic hydrocarbon polymer containing one or two or more sulfonic acid groups selected from the following polymers (A<sup>1</sup>) and (A<sup>2</sup>)

(A<sup>1</sup>) a polymer that is a polymer obtained by polymerizing one or two or more monomers selected from (a) a polymerizable aromatic sulfonic acid monomers and (b) a polymerizable hydrocarbon monomer group and that contains the above-described constituent (a) as its essential constituent

(A<sup>2</sup>) a polymer that is a polymer obtained by polymerizing one or two or more monomers selected from a polymerizable hydrocarbon monomer group and which is obtained by sulfonation of a polymer that contains at least one polymerizable aromatic monomer as its essential constituent

and

(B): a polymer of one or two or more monomers selected from unsaturated carboxylic acid esters as represented by general formula I





(wherein, R<sup>1</sup>, R<sup>2</sup> and R<sup>3</sup> are selected from -H, -CH<sub>3</sub>, -COO(R<sup>4</sup>O)<sub>m</sub>H and -CH<sub>2</sub>COO(R<sup>5</sup>O)<sub>n</sub> and that contains at least one -H and at least one -COO(R<sup>4</sup>O)<sub>m</sub> or -CH<sub>2</sub>COO(R<sup>5</sup>O)<sub>n</sub>H group; provided that m and n are from 1 to 60, R<sup>4</sup> and R<sup>5</sup> are alkylene groups of 2 to 4 carbon atoms, and, when m or n is 2 or greater, the repeating plurality of R<sup>5</sup> and R<sup>6</sup> may be the same alkyl groups or may be alkylene groups with different numbers of carbon atoms.)

### Detailed Description of the Invention

#### Technical Field

This invention relates to a dispersant that is used in an aqueous slurry of carbonaceous fine powder as typified by coal and petroleum coke.

#### Prior Art

From the standpoint of increases in oil prices and the diversification of energy resources, attention has been drawn in recent years to the use of coal. Because coal is solid fuel and there are difficulties in handling it, it has been proposed that it be finely pulverized and made into an aqueous slurry. As a result of making solid fuels such as coal and petroleum coke into aqueous slurries, transport by pipe becomes possible and it becomes possible to handle them in the same manner as liquid fuels. An aqueous slurry is combusted in unaltered form without dehydration treatment, and it needs to be highly concentrated from the standpoint of transport efficiency. However, it is difficult to obtain a highly concentrated slurry of 50% or greater merely by dispersing a carbonaceous fine powder such as coal and petroleum coke in water in unaltered form. In addition, when allowed to stand, a carbonaceous fine powder will precipitate and become non-uniform, leading to the problem of storage stability.

Accordingly, the addition of a dispersion stabilizer into the slurry has been proposed for providing high concentrations and improving dispersion stability. Dispersion stabilizers of this kind that have been reported include, for example, naphthalene sulfonic acid formalin condensates (Japanese Patent Application Early Disclosure No. S56-21636 [1981]), copolymers of acrylic acid or methacrylic acid and other vinyl monomers (Japanese Patent Application Early Disclosure No. S56-57890 [1981]), copolymers of acrylic acid and maleic acid (Japanese Patent Application Early Disclosure No. S56-57890 [1981]), cross-linked polyether compounds in which alkylene oxide additives having active hydrogen groups in the molecule are cross-linked (Japanese Patent Application Early Disclosure No. S58-118893 [1983]), sulfonated coal tar or formaldehyde condensates (Japanese Patent Application Early Disclosure No. S58-23889 [1983]), and additives that contain water-soluble aromatic polymers such as salts of copolymers of styrene sulfonic acid and vinyl compounds and water-soluble aliphatic polymers such as copolymers of α-olefins and maleic anhydride or acrylic acid (Japanese Patent Application Early Disclosure No. S59-166591 [1984]).

However, while some effects have been seen with these conventional dispersants, either high concentration or static stability of the slurries has been inadequate and further improvements have been desired.

#### Object of the invention

An object of the present invention is to provide, when added to an aqueous slurry of a carbonaceous fine powder, a dispersant with which a highly concentrated slurry of low viscosity and superior improvement in fluidity may be realized and with which static stability for long periods may be obtained.

## Structure of the Invention

The dispersant for an aqueous slurry of carbonaceous fine powder of this invention is characterized in that it contains constituent (A) and constituent (B) as indicated below.

Constituent (A): an aromatic hydrocarbon polymer containing one or two or more sulfonic acid groups selected from the following polymers (A<sup>1</sup>) and (A<sup>2</sup>)

(A<sup>1</sup>) a polymer that is a polymer obtained by polymerizing one or two or more monomers selected from (a) a polymerizable aromatic sulfonic acid monomers and (b) a polymerizable hydrocarbon monomer group and that contains the above-described constituent (a) as its essential constituent

(A<sup>2</sup>) a polymer that is a polymer obtained by polymerizing one or two or more monomers selected from a polymerizable hydrocarbon monomer group and which is obtained by sulfonation of a polymer that contains at least one polymerizable aromatic monomer as its essential constituent

Constituent (B): a polymer of one or two or more monomers selected from unsaturated carboxylic acid esters as represented by general formula I



(wherein, R<sup>1</sup>, R<sup>2</sup>, and R<sup>3</sup> are selected from -H, -CH<sub>3</sub>, -COO(R<sup>4</sup>O)<sub>m</sub>H, and -CH<sub>2</sub>COO(R<sup>5</sup>O)<sub>n</sub> and contain at least one -H and at least one -COO(R<sup>4</sup>O)<sub>m</sub> or -CH<sub>2</sub>COO(R<sup>5</sup>O)<sub>n</sub>H group; provided that m and n are from 1 to 60, R<sup>4</sup>O and R<sup>5</sup> are alkylene groups of 2 to 4 carbon atoms, and, when m or n is 2 or greater, the repeating plurality of R<sup>5</sup> and R<sup>6</sup> may be the same alkyl groups or may be alkylene groups with different numbers of carbon atoms.)

We shall now describe this invention in greater detail. The polymer of constituent (A) contains aromatic hydrocarbon containing sulfonic acid groups in the molecule as its structural units. The polymers of (A<sup>1</sup>) are substances in which the sulfonic acid groups are substances originating from monomers and, specifically, they are substances in which aromatic hydrocarbon monomers containing sulfonic acid groups are polymerized independently or with other monomers. On the other hand, the polymers of (A<sup>1</sup>) are substances in which monomers are polymerized and polymers are obtained, after which the sulfonic acid groups are introduced into the aromatic groups in the polymers.

The polymers of (A<sup>1</sup>) are polymers that consist of one or more monomers selected from group (a) and group (b) as indicated below and are substances that contain structural units originating from at least group (a) monomers.

- (a) Polymerizable aromatic sulfonic acid monomers
- (b) Polymerizable hydrocarbon monomers

The proportion of group (a) aromatic sulfonic acid monomers in the polymers of (A<sup>1</sup>) should be from 40 to 100 mol%, and, preferably, from 50 to 100 mol%. The polymer of (A<sup>1</sup>) may also be constructed solely of group (a) aromatic sulfonic acid monomers without using group (b) monomers.

Specific examples of group (a) monomers may include styrene sulfonic acid, α-methylstyrenesulfonic acid, vinyl toluene sulfonic acid, vinyl naphthalene sulfonic acid, or salts thereof. The counterions that form the salts may be monovalent metals such as sodium and

potassium, divalent metals such as magnesium and calcium, trivalent metals such as aluminum and ammonium and organic amines. Of these, sodium, potassium, and ammonium are preferable.

Specific examples of group (b) monomers may include styrene,  $\alpha$ -methylstyrene, vinyltoluene, ethylene, butene, butadiene, and diisobutylene.

Examples of copolymers of group (a) monomers and group (b) monomers may include styrenesulfonic acid – styrene copolymers, styrenesulfonic acid – butadiene copolymers, styrenesulfonic acid – butene copolymers,  $\alpha$ -methyl styrenesulfonic acid – ethylene copolymers, and  $\alpha$ -methyl styrenesulfonic acid – diisobutylene copolymers.

The molecular weight of the polymer of ( $A^1$ ) should correspond to a weight average molecular weight of 700 to 700,000, and, preferably, of 1000 to 500,000.

The polymers of ( $A^2$ ) are sulfonated polymers or salts thereof that contain at least one polymer of hydrocarbon monomers and at least one aromatic monomer as essential constituents. These aromatic monomers may include styrene,  $\alpha$ -methylstyrene, vinyltoluene, vinylnaphthalene, and indene. In addition, the hydrocarbon monomers other than aromatic monomers may include ethylene, butene, butadiene, and diisobutylene. The proportion of aromatic monomers in these monomers should be from 30 to 100 mol%, and, preferably, from 50 to 100 mol%. Specific examples of these polymers include petroleum resins such as polystyrene, styrene-ethylene copolymers, styrene – diisobutylene copolymers, and styrene - vinyltoluene -  $\alpha$ -methylstyrene - indene copolymers. The polymers of ( $A^2$ ) are obtained by the sulfonation of these polymers or by making them into salts. Sulfonation may be performed using sulfonating agents such as sulfuric acid anhydride, chlorosulfonic acid, and sulfuric acid anhydride – Lewis base complex and by applying any desired sulfonation method. The molecular weight of the polymer of ( $A^2$ ) should be a weight average molecular weight of 700 to 700,000, and, preferably, from 1000 to 500,000. Examples of salts of the polymers of ( $A^2$ ) are the same as those of the polymers of ( $A^1$ ).

The aromatic hydrocarbon polymers containing sulfonic acid groups of constituent (A) may also be used by mixing the polymer of ( $A^1$ ) and the polymer of ( $A^2$ ) in any desired proportions.

The polymer of unsaturated carboxylic acid ester monomers of constituent (A) may be obtained by the addition polymerization of alkylene oxides of 2 to 4 carbon atoms with an  $\alpha$ ,  $\beta$ -unsaturated carboxylic acid or by an esterification reaction with a polyoxyalkylene glycol. Specific examples of  $\alpha$ ,  $\beta$ -unsaturated carboxylic acids include monocarboxylic acids such as acrylic acid, methacrylic acid, and crotonic acid, and dicarboxylic acids such as fumaric acid, maleic acid, and itaconic acid. In addition, specific examples of alkylene oxides include ethylene oxide (EO), propylene oxide (PO), and 1,2-butylene oxide (BO). The alkylene oxide may be added independently or as a mixture of two or more alkylene oxides. Taking into consideration the solubility of constituent (B) in water, it is preferable to use at least ethylene oxide, and, more preferably, that 50 mol% or greater of the added alkylene oxide be ethylene oxide. The form of addition of the alkylene oxide may be a block polymer or a random polymer, or the ethylene oxide may be added to the terminal. The number of moles of alkylene oxide added is in the range of 1 to 60 moles per carboxyl group. When it exceeds 60 moles, the dispersibility of the aqueous slurry of carbonaceous fine powder deteriorates when it is compounded with constituent (A).

Specific examples of constituent (B) are indicated below.

Polymers of polyoxyethylene monoacrylate (two EO units added per molecule of acrylic acid) (average molecular weight: 6000).

Polymers of polyoxypropylene-polyoxyethylene methacrylate (to which 10 PO units and then 20 EO units per molecule of methacrylic acid (average molecular weight: 200,000) are block added.

Copolymers of (a) EO additive of maleic acid (addition of two EO units to each of two active hydrogen atoms of a molecule of maleic acid) and (b) polyoxyethylene monoacrylate (addition of 5 EO units per molecule of acrylic acid) {(a)/(b) = 1/3; average molecular weight: 100,000}.

Polymers of EO additives of itaconic acid (addition of one EO unit each to two active hydrogen atoms (average molecular weight: 2000).

Polymers of EO additives of butylene oxides of acrylic acid ((B)O) (random addition of 2 moles of (B)O and 20 moles of EO per molecule of acrylic acid) (average molecular weight: 100,000).

Copolymers of EO additives of crotonic acid (addition of one EO unit per mole) and EO additives of methacrylic acid (addition of 5 EO units per mole) (average molecular weight: 40,000).

The polymer of an unsaturated carboxylic acid ester monomer of constituent (B) should be a weight average molecular weight of 1000 to 400,000, and, preferably, from 2000 to 300,000. When the molecular weight is less than 1000, static stability deteriorates when it is compounded with constituent (A). When the molecular weight exceeds 400,000, dispersibility deteriorates.

The compounding of constituent (A) and constituent (B) should be in the range of constituent (A)/ constituent (B) = 1/9 to 20/1 ratio by weight, and, preferably, in the range of 1/5 to 15/1. When this ratio is less than 1/9, dispersibility deteriorates, and, when it exceeds 15/1, static stability deteriorates.

A cross-linking agent may be used during polymerization of constituent (A) or constituent (B) of this invention. Examples of cross-linking agents include divinylbenzene, methylene-bis-acrylamide, ethylene glycol dimethacrylate, diethylene glycol dimethacrylate, polyethylene glycol dimethacrylate, trimethylolpropane dimethacrylate, trimethylolpropane trimethacrylate, and diallyl phthalate. For both constituents (A) and (B), 0 to 5 mol% of cross-linking agent should be used, with 0.01 to 3 mol% being preferable. When an excessive quantity of cross-linking agent is compounded, water solubility is decreased, which is not desirable.

The dispersant of this invention should be added to the aqueous slurry of carbonaceous fine powder so that it is present in a range of 0.05 to 3 % by weight, and, preferably, of 0.1 to 2 % by weight.

The carbonaceous fine powders that are used may be substances that are used as an energy source such as coals such as anthracite coal, bituminous coal, and sub-bituminous coal, petroleum coke, carbon black produced as a by-product from chemical plants, carbon black obtained by carbonization of organic substances, and charcoal.

In addition, for substances containing a high ash content such as coal, the flotation method and the granulation in water method (oil agglomeration method) should be used to perform decalcification, desulfurization and cleaning. These carbon sources are made into fine powders so that they essentially do not contain more than 1 mm of matter. Taking into consideration combustibility as fuels, it is desirable that a content of less than 74  $\mu\text{m}$  account for more than 50 % by weight, and, preferably, 60 to 100 % by weight.

The aqueous slurry of carbonaceous fine powder may be obtained by pulverizing the carbonaceous substance by the dry pulverization method or the wet pulverization method to make an aqueous slurry. The dispersant may be added in a suitable process so that it will be contained in the final aqueous slurry. For example, when the carbonaceous fine powder is obtained by the dry pulverization method, the dispersant is dissolved or dispersed in water, fine powder is added, and a highly concentrated aqueous slurry may be prepared by means of a suitable mixing device. In addition, when the wet pulverization method is used, the dispersant

may be added to the water prior to performing the wet pulverization, or it may be added during or after the wet pulverization takes place.

The concentration of carbonaceous fine powder in the aqueous slurry depends on the type of fine powder, the average particle diameter, and particle size distribution. It may be increased sufficiently by adding the dispersant pertaining to this invention. For example, the concentration may be increased to as much as 80 % by weight.

### **Effects of the Invention**

With the dispersant of this invention, the fluidity and static stability of an aqueous slurry of carbonaceous fine powder may be synergistically improved through combined use of (A) the aromatic hydrocarbon polymer containing sulfonic acid groups and (B) the polymer of unsaturated carboxylic acid ester monomers. By this means, an aqueous slurry of a higher concentration than of conventional substances may be obtained and may be stored stably over a long period.

An aqueous slurry of carbonaceous fine powder to which the stabilizer of this invention has been added may be used as a boiler fuel for electric power and general industrial use but may also be used as an auxiliary fuel for cutting back on the use of coke in blast furnaces and metallurgic furnaces in the field of steel manufacturing.

### **Working Examples**

A prescribed dispersant was dissolved in water and small quantities of carbonaceous fine powder were added to it at room temperature so as to give a predetermined quantity (dry standard). After the addition of the total amount had been completed, the product was stirred for 10 minutes at 3000 rpm in a homomixer (manufactured by Tokushu Kika Kogyo) and approximately 500 grams of aqueous high concentration slurry was prepared.

Next, the fluidity and static stability of this slurry were evaluated.

#### **(1) Fluidity**

Viscosity was measured at 25°C.

O: excellent

Δ: insufficient

X: poor

#### **(2) Static stability**

The entire amount of the slurry was introduced into a 500 ml cylinder with an inside diameter of 6 cm and a glass rod with a diameter of 5 mm, a length of 40 cm, and a weight of 50 g was allowed to fall naturally from the surface of the above-described slurry. The time until it reached the bottom of the cylinder was then measured twice, immediately after preparation and after standing for one month at room temperature, which times were taken as rod penetration time. The longest measurement time was up to 180 seconds. In cases in which more time was required, the height that had been reached from the bottom by this time was measured as the height of the consolidation layer.

O: excellent

X: poor

The particle size distribution of the carbonaceous fine powder used in preparation of the aqueous slurry is shown in Table 1 and the analytic values for coal are shown in Table 2.

The properties of constituent (A) of the dispersant of this invention are shown in Table 3 and the properties of constituent (B) are shown in Table 4.

The measurement results for aqueous slurries in which the dispersant of this invention was used and in which constituent (A) and constituent (B) were compounded shown in Table 5.

As comparative examples, Table 6 shows the results of determinations of a case in which dispersant was not added (Experimental Example No. 65), cases in which constituent (A) or constituent (B) of this invention were used independently (Experimental Examples Nos. 66 and 67) and representative examples of known dispersants (Experimental Examples No. 68 to 70).

**Table 1**  
**Particle Size Distributions of Carbonaceous Fine Powders**

Abbreviation	CP-I	CP-II	CP-III	CP-IV
Carbonaceous fine powder	Coal mountain char	Datong char	Berga [phonetic] char	Petroleum coke
Particle size				
Particle size distribution (wt %)	+200#	18.8	19.3	19.5
	200# ~ 325#	12.6	13.1	13.5
	-325#	68.6	67.6	67.0
				74.2

**Table 2**  
**Properties of Coal**

Item analyzed	Coal	CP-I	CP-II	CP-III
Industrial analysis	Water content (%)	8.0	3.5	15.9
	Ash content (%)	14.0	12.3	7.5
	Volatile content (%)	21.0	28.4	51.4
	Fixed carbon (%)	57.0	59.3	41.1
Elemental analysis	C (%)	76.2	68.9	67.1
	H (%)	4.1	4.1	5.3
	O (%)	6.0	13.3	19.4
	N (%)	1.2	0.9	0.7
	S (%)	0.2	0.9	0.1
Production region	Canada	China	China	America

**Table 3**  
**Properties of Constituent (A)**

Polymer No.	(a) Polymerizable aromatic sulfonic acid monomer	(b) Polymerizable hydrocarbon monomer			(a)/(a) + (b) × 100
		(b)-1 Aromatic	(b)-2 Aliphatic	$\frac{\{(b)-1\} \times 100}{\{(b)-1 + (b)-2\}}$ (mol%)	
A-1	styrene sulfonic acid	-	-	-	100
A-2	styrene sulfonic acid	-	-	-	100
A-3	$\alpha$ -methyl styrene sulfonic acid	styrene	-	100	60
A-4	vinyl styrene sulfonic acid	-	ethylene	0	50
A-5	styrene sulfonic acid	-	butadiene	0	80
A-6	styrene sulfonic acid	-	-	-	100
A-7	-	styrene	-	100	0
A-8	-	styrene	-	100	0
A-9	-	$\alpha$ -methyl styrene	propylene	50	0
A-10	-	styrene	diisobutylene	80	0
A-11	-	styrene, vinyl toluene, $\alpha$ -methyl styrene, indene	-	100	0
A-12	-	styrene, vinyl toluene, $\alpha$ -methyl styrene, indene	-	100	0
A-13	-	styrene	butadiene	60	0

Polymer No.	Cross-linking agent		Polymer sulfonated or not	Product	
	Type	Quantity added (mol% per monomer)		Average molecular weight	Counterion
A-1	-	-	no	50,000	Na
A-2	-	-	no	10,000	NH <sub>4</sub>
A-3	-	-	no	150,000	Mg
A-4	-	-	no	250,000	monoethanolamine
A-5	-	-	no	80,000	diethylene triamine
A-6	divinyl benzene	2.0	no	500,000	NH <sub>4</sub>
A-7	-	-	yes	1000	NH <sub>4</sub>
A-8	-	-	yes	100,000	Ca
A-9	-	-	yes	30,000	Na
A-10	-	-	yes	8000	Mg
A-11	-	-	yes	3000	NH <sub>4</sub>
A-12	methylene-bis-acrylamide	3.0	yes	10,000	triethanolamine
A-13	-	-	yes	200,000	K

Table 4  
**Properties of Constituent (B)**  

$$\begin{array}{c} R^1 = R^2 \\ | \qquad | \\ CH=CH-R^3 \end{array}$$

No.	Monomer M <sub>1</sub>			Monomer M <sub>2</sub>		
	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>
B-1	H	H	COO(EO) <sub>2</sub> H	-	-	-
B-2	H	H	COO(EO) <sub>40</sub> H	-	-	-
B-3	H	CH <sub>3</sub>	COO(PO) <sub>10</sub> (EO) <sub>20</sub> H	-	-	-
B-4	H	COO(EO) <sub>1</sub> H	CH <sub>2</sub> COO(EO) <sub>1</sub> H	-	-	-
B-5	H	H	COO{(BO) <sub>2</sub> (EO) <sub>20</sub> }H (random addition)	-	-	-
B-6	H	H	COO(EO) <sub>5</sub> H	COO(EO) <sub>3</sub> H	H	COO(EO) <sub>3</sub> H
B-7	H	H	COO(BO) <sub>3</sub> (EO) <sub>8</sub> H	H	COO(EO) <sub>5</sub> H	CH <sub>2</sub> COO(EO) <sub>5</sub> H
B-8	H	CH <sub>3</sub>	COO(BO) <sub>1</sub> (EO) <sub>10</sub> H	CH <sub>3</sub>	H	COO(EO) <sub>2</sub> H
B-9	H	CH <sub>3</sub>	COO(EO) <sub>15</sub> H	H	CH <sub>3</sub>	COO(PO) <sub>2</sub> (EO) <sub>10</sub> H

No.	M <sub>1</sub> /M <sub>2</sub> (molar ratio)	Cross-linking agent		Average molecular weight of polymer
		Type	Quantity added mol% v. monomer	
B-1	1/0	-	-	60,000
B-2	1/0	-	-	200,000
B-3	1/0	ethylene glycol diacrylate	1.0	300,000
B-4	1/0	-	-	2000
B-5	1/0	-	-	100,000
B-6	3/1	-	-	70,000
B-7	5/1	-	-	15,000
B-8	4/1	-	-	26,000
B-9	2/1	trimethylol propane trimethacrylate	0.5	140,000

- Note 1) The substances designated by M<sub>1</sub> and M<sub>2</sub> are monomers that form the copolymer.
- 2) EO: indicates ethylene oxide units; PO: indicates propylene oxide units; BO: indicates butylene oxide units.
- 3) The formulas in all cases except B-5 indicate block addition when two types of alkylene oxides are added to a molecule of monomer.

**Table 5**  
**Measurements (Working Examples of this Invention)**

Experiment No.	Dispersant			Carbonaceous fine powder		Fluidity		Static stability			Evaluation
	Constituent (A)	Constituent (B)	(A)/(B) (weight ratio)	Amount added (wt% vs. carbonaceous substance)	Type	Slurry concentration	Slurry viscosity (25°C, CP)	Evaluation	Rod penetration time (seconds)	Immediately after	After 1 month
1	A-1	B-1	8/2	0.5	CP-I	70	840	O	3	8	O
2	A-1	B-2	8/2	0.5	CP-I	70	800	O	4	6	O
3	A-1	B-3	8/2	0.5	CP-I	70	960	O	3	7	O
4	A-2	B-4	5/5	0.5	CP-I	70	720	O	3	7	O
5	A-2	B-5	5/5	0.5	CP-I	70	680	O	2	8	O
6	A-2	B-6	5/5	0.5	CP-I	70	840	O	3	8	O
7	A-3	B-7	3/7	0.5	CP-I	70	660	O	2	7	O
8	A-7	B-8	3/7	0.5	CP-I	70	680	O	2	7	O
9	A-8	B-9	3/7	0.5	CP-I	70	730	O	3	7	O
10	A-13	B-9	3/7	0.5	CP-I	70	790	O	3	7	O
11	A-13	B-7	5/5	0.8	CP-I	73	920	O	3	9	O
12	A-2	B-7	5/5	0.8	CP-I	73	1060	O	3	8	O
13	A-4	B-7	5/5	0.8	CP-I	73	1100	O	3	8	O
14	A-5	B-4	5/5	0.8	CP-I	73	1010	O	3	7	O
15	A-6	B-4	10/1	1.0	CP-I	73	960	O	3	9	O
16	A-9	B-4	10/1	1.0	CP-I	73	990	O	3	9	O
17	A-10	B-5	10/1	1.0	CP-I	73	910	O	3	8	O
18	A-11	B-6	10/1	1.0	CP-I	73	880	O	3	8	O
19	A-12	B-6	15/1	1.0	CP-I	73	1000	O	3	6	O
20	A-12	B-7	15/1	1.0	CP-I	73	1070	O	3	6	O
21	A-1	B-2	5/5	0.7	CP-II	70	720	O	3	5	O
22	A-1	B-3	5/5	0.7	CP-II	70	780	O	3	6	O
23	A-1	B-7	5/5	0.7	CP-II	70	760	O	3	6	O
24	A-2	B-8	5/5	0.7	CP-II	70	770	O	3	5	O
25	A-2	B-9	5/5	0.7	CP-II	70	890	O	3	6	O
26	A-2	B-9	7/3	0.7	CP-II	70	920	O	3	6	O
27	A-3	B-4	7/3	0.7	CP-II	70	920	O	3	6	O

Experiment No.	Dispersant				Carbonaceous fine powder		Fluidity		Static stability		
	Constituent (A)	Constituent (B)	(A)/(B) (weight ratio)	Amount added (wt% vs. carbonaceous substance)	Type	Slurry concentration	Slurry viscosity (25°C, CP)	Evaluation	Rod penetration time (seconds)		Evaluation
									Immediately after	After 1 month	
28	A-3	B-4	1/5	0.7	CP-II	70	750	O	2	6	O
29	A-3	B-4	10/1	1.0	CP-II	70	690	O	2	8	O
30	A-8	B-5	5/5	1.0	CP-II	70	650	O	2	8	O
31	A-10	B-5	5/5	1.0	CP-II	70	680	O	2	7	O
32	A-10	B-6	5/5	1.0	CP-II	70	910	O	3	6	O
33	A-1	B-6	5/5	0.6	Clean CP-II*	73	1020	O	4	7	O
34	A-1	B-7	5/5	0.6	"	73	1100	O	4	7	O
35	A-1	B-8	5/5	0.6	"	73	1240	O	4	7	O
36	A-2	B-4	10/1	0.6	"	73	970	O	3	7	O
37	A-2	B-4	8/2	0.6	"	73	960	O	3	8	O
38	A-2	B-4	3/7	0.6	"	73	840	O	3	6	O
39	A-13	B-1	3/7	0.9	"	73	690	O	2	5	O
40	A-13	B-2	3/7	0.9	"	73	650	O	2	8	O
41	A-13	B-3	3/7	0.9	"	73	600	O	2	8	O
42	A-13	B-9	3/7	0.9	"	73	710	O	2	8	O
43	A-7	B-4	1/5	1.0	CP-III	65	1200	O	4	7	O
44	A-7	B-5	1/5	1.0	CP-III	65	1260	O	4	7	O
45	A-11	B-6	5/5	1.0	CP-III	65	1370	O	4	7	O
46	A-11	B-7	5/5	1.0	CP-III	65	1290	O	4	7	O
47	A-11	B-8	5/5	1.0	CP-III	65	1330	O	4	7	O
48	A-2	B-6	8/2	1.2	CP-III	70	1400	O	4	8	O
49	A-2	B-6	4/6	1.2	CP-III	70	1410	O	5	8	O
50	A-2	B-7	10/1	1.2	CP-III	70	1360	O	4	8	O
51	A-8	B-8	7/3	1.2	CP-III	70	1500	O	5	7	O
52	A-8	B-9	7/3	1.2	CP-III	70	1380	O	4	8	O
53	A-7	B-4	6/4	0.3	CP-IV	70	920	O	3	9	O
54	A-7	B-5	6/4	0.3	CP-IV	70	800	O	3	9	O
55	A-7	B-6	6/4	0.3	CP-IV	70	740	O	2	6	O
56	A-9	B-6	8/2	0.3	CP-IV	70	790	O	2	6	O
57	A-10	B-6	10/1	0.4	CP-IV	72	890	O	3	9	O

Experiment No.	Dispersant			Carbonaceous fine powder		Fluidity		Static stability			
	Constituent (A)	Constituent (B)	(A)/(B) (weight ratio)	Amount added (wt% vs. carbonaceous substance)	Type	Slurry concentration	Slurry viscosity (25°C, CP)	Evaluation	Rod penetration time (seconds)		Evaluation
									Immediately after	After 1 month	
58	A-10	B-1	5/5	0.4	CP-IV	72	810	O	3	8	O
59	A-10	B-2	6/4	0.4	CP-IV	72	720	O	2	7	O
60	A-11	B-5	4/6	0.4	CP-IV	72	760	O	2	7	O
61	A-1	B-6	4/6	0.5	CP-IV	75	1060	O	3	8	O
62	A-1	B-7	4/6	0.5	CP-IV	75	1020	O	3	8	O
63	A-1	B-8	2/8	0.5	CP-IV	75	980	O	3	9	O
64	A-1	B-9	2/8	0.5	CP-IV	75	900	O	3	8	O

\* Processed by coal flotation method; decalcification rate - 50%

Table 6  
Measurements (Comparative Examples)

Experiment No.	Dispersant		Carbonaceous fine powder		Fluidity		Static stability		
	Type	Amount added (wt% vs. carbonaceous substance)	Type	Slurry concentration	Slurry viscosity (25°C, CP)	Evaluation	Rod penetration time (seconds)		Evaluation
							Immediately after	After 1 month **	
65	Not used	-	CP-I	53	Unable to make into slurry	X	Unable to evaluate		
66	A-1	1.0	CP-I	73	940	O	3	180 < (15 cm)	X
67	B-1	1.0	CP-I	68	1200	O	4	180 < (13 cm)	X
68	formaldehyde condensate of sodium naphthalenesulfonate	1.0	CP-I	63	6200	Δ	8	135	Δ
69	Sodium polyacrylate (molecular weight, 10,000)	1.0	CP-I	60	5400	Δ	12	180 < (12 cm)	X
70	Quantity of addition PO, EO block addition of propylene glycol (molecular weight of PO component: 3000; molecular weight of EO component: 3000)***	1.0	CP-I	63	4500	Δ	12	180 < (15 cm)	X

\*\* The numbers inside the ( ) marks under the rod penetration test indicate the consolidation layer in centimeters.

\*\*\* PO: Propylene oxide; EO: Ethylene oxide